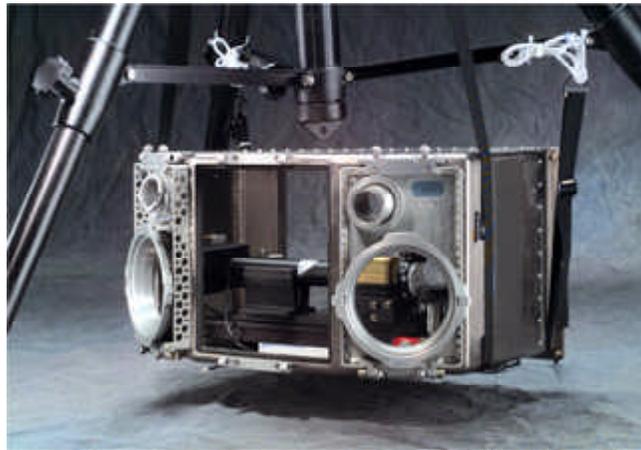


Phase-Shifted Laser Feedback Interferometry

Phase-shifted, laser feedback interferometry is a new diagnostic tool developed at the NASA Lewis Research Center under the Advanced Technology Development (ATD) Program directed by NASA Headquarters' Microgravity Research Division. It combines the principles of phase-shifting interferometry (PSI) and laser-feedback interferometry (LFI) to produce an instrument that can quantify both optical path length changes and sample reflectivity variations. In a homogenous medium, the optical path length between two points is the product of the index of refraction and the geometric distance between the two points. LFI differs from other forms of interferometry by using the laser as both the source and the phase detector. In LFI, coherent feedback of the incident light either reflected directly from a surface or reflected after transmission through a region of interest will modulate the output intensity of the laser. The combination of PSI and LFI has produced a robust instrument, based on a low-power helium-neon (HeNe) gas laser, with a high dynamic range that can be used to measure either static or oscillatory changes of the optical path length. Small changes in optical path length are limited by the fraction of a fringe that can be measured; we can measure nonoscillatory changes with a root mean square (rms) error of the wavelength/1000 without averaging.



Phase-shifted, laser feedback interferometer installed in a replica of a "glove-box" used aboard the space shuttle. The light from a helium-neon laser (black cylinder) illuminates an object, which is scanned under the laser beam. The gold box between the laser and the object is a phase modulator that is used to introduce controlled phase shifts. A photodetector (black box on the far left side) is used to monitor the laser's intensity.

The preceding photograph shows the phase-shifted, laser feedback interferometer installed in a replica of the "glove-box" that was used aboard the space shuttle. The laser can be observed just behind the center panel (which was intentionally left open). To the left of the laser is a photodetector, and to the right is the electro-optic modulator (gold box) used to introduce the phase shifts. To achieve higher spatial resolution, we coupled the

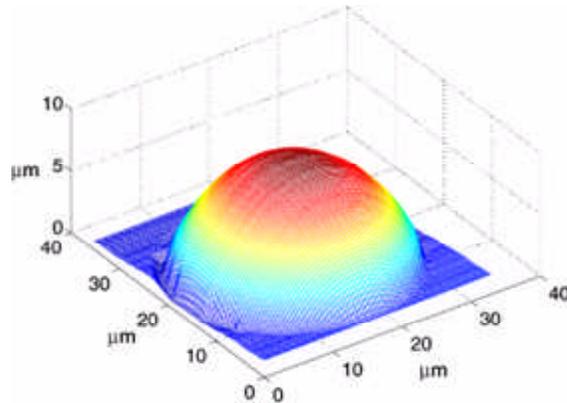
interferometer with a high numerical aperture objective and placed the sample to be scanned at the focus of the objective. The glove box was suspended from elastic cords to isolate the apparatus from vibrations. The following photograph shows an expanded view of the electro-optic modulator, the corner cube used to bend the laser beam, and the microscope objective. A demonstration of this apparatus was recently provided at the Third Microgravity Fluid Physics Conference, and changes in the optical path length as small as 5 nanometers (nm) were readily achieved even during times of heavy pedestrian traffic.



Scanning of an object in the interferometer. After the light leaves the phase modulator (gold box), it crosses a polarizer and is bent downward by a corner cube (glass) and

focused by a microscope objective. An object is scanned across the focused laser beam to determine its topology.

We also combined the phase-shifted, laser feedback interferometer with a reflecting light microscope and obtained images of contours of static fluid drops on coated silicone substrates. The next figure shows the optical path length through a silicone oil drop. This image, which was obtained by scanning the drop beneath a fixed laser beam, clearly shows the edge of the drop. We are currently pursuing the measurement of dynamic fluid-solid interfaces.



Optical path length through a silicone oil drop on a coated silicon substrate. A spherical drop has been correctly reconstructed.

Bibliography

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